SMITHSONIAN CONTRIBUTIONS TO KNOWLEDGE.

DISCUSSION

OF THE

MAGNETIC AND METEOROLOGICAL OBSERVATIONS

MADE AT THE GIRARD COLLEGE OBSERVATORY, PHILADELPHIA,
IN 1840, 1841, 1842, 1843, 1844, AND 1845.

PART I.

INVESTIGATION OF THE ELEVEN YEAR PERIOD IN THE AMPLITUDE OF THE SOLAR-DIURNAL VARIATION AND OF THE DISTURBANCES OF THE MAGNETIC DECLINATION.

BY

A. D. BACHE, LL. D.

[ACCEPTED FOR PUBLICATION, JUNE, 1859.]

COMMISSION

TO WHICH THIS MEMOIR HAS BEEN REFERRED.

Prof. BENJ. PEIRCE,
Prof. W. CHAUVENET.

JOSEPH HENRY,
Secretary S. I.

COLLINS, PRINTER,
PHILADELPHIA.

INTRODUCTION.

In co-operation with the scheme adopted at the British colonial observatories, a series of magnetic and meteorological observations were made at the Girard College magnetic observatory, in Philadelphia, with instruments purchased under the direction of the trustees of the college, the observations being made under the patronage of the American Philosophical Society, and finally completed for the use of the topographical bureau of the War Department.[1] These observations were made under my immediate direction, and were afterwards left under my general superintendence. The series commenced in May, 1840, and, with short interruptions, terminated in June, 1845, thus furnishing a five years' series of magnetic observations, taken bi-hourly up to October, 1843, and after that date hourly. The readings of each magnetic element were united into mean values, arranged according to hours of the day and days of the month and annual values, and presented graphically, under my direction, by Joseph S. Ruth, Esq., who had taken part in the observations, and who was at that time employed in the Coast Survey. As, owing to other laborious duties, the record could not then be submitted to a complete reduction and discussion, I have resumed the subject, with the aid of Charles A. Schott, Esq., assistant in the Coast Survey, by whom, under my immediate direction, the discussions contained in this paper have been made and prepared for publication. It is proper to state that this work has been performed out of office hours by Mr. Schott, as my assistant in this special matter, and at my own expense.

Although the magnetic observatories furnished by their judicious geographical location, a basis for the generalization of their results, it is, nevertheless, desirable to combine other results with them as confirmations, or as corrections. In the investigation of the disturbance law at Point Barrow, as compared with the same at Toronto, a very remarkable mutual relation was developed, and further examination may bring to light other dependencies of a mutual character.

According to the latest determination, the position of the Girard College observatory is in latitude 39° 58′ 23″ (north), and in longitude 75° 10′ 05″ = $5^h\ 00^m\ 40^s.3$

[1] See "Observations at the magnetic and meteorological observatory at the Girard College, Philadelphia, made under the direction of A. D. Bache, LL. D., and with funds supplied by the members of the American Philosophical Society and by the Topographical Bureau of the United States, 1840 to 1845. Printed by order of the Senate of the United States, and under the direction of the Topographical Bureau, second session of the twenty-ninth Congress. Washington, D. C., 1847." Three volumes record and one volume plates.

west of Greenwich.[1] From Philadelphia, Toronto bears 38° 45′ west of north (true), and is distant 4° 50′ in arc, or about 334 statute miles.

It is proposed in the present paper to investigate the law of the eleven year period, or as it is more frequently called, the decennial period, there being yet an uncertainty as to its precise length. It is supposed to have some direct or indirect connection with the solar spot period, which, according to late investigations by Prof. R. Wolf,[2] is said to exhibit corresponding disturbances.

The discussion is a contribution towards the determination of the epoch of the occurrence of a minimum (as to number and magnitude) in certain phases of the magnetic variations and disturbances, corresponding to a minimum in the solar spot period. The method of reduction is substantially the same as that adopted by General Sabine, and explained in his discussion of the Toronto and Hobarton[3] observations.

---

[1] This longitude depends on that of Cambridge observatory, for which $4^h\ 44^m\ 30^s.25$ has been adopted.

[2] Astronomische Nachrichten, No. 1091 (May, 1857).

[3] See three papers by General Sabine, on periodical laws discoverable in the mean effects of the larger magnetic disturbances. Philosophical Transactions of the Royal Society, 1851, 1852, and 1856.

INVESTIGATION OF THE ELEVEN YEAR PERIOD

IN THE

CHANGE OF THE AMPLITUDE OF THE SOLAR-DIURNAL VARIATION OF THE MAGNETIC DECLINATION, COMPRISING THE REGULAR AS WELL AS THE DISTURBED DIURNAL VARIATION.

WHILE the magnitude of the deflection is the only criterion for the recognition of a disturbance, the adoption of any limit of deviation from the normal value for the same hour, month, and year, must necessarily remain in some measure arbitrary, or, in other words, there must always remain, after the separation of the disturbances, a certain small amount of their effect in the remaining regular diurnal progression. General Sabine has shown that the results are not sensibly affected by a small variation in the line of separation of the disturbed from the undisturbed readings.[1]

To effect the separation, I made use of Peirce's criterion,[2] for the rejection of doubtful observations, applying it, however, to observations following a law different from the regular one.[3] From an examination of 465 hourly observations, distributed over different hours of the day and different months of the year, the following was the limit of separation:—

$9^d.3$	from six months	in	1840
8.1	"	"	1843
6.0	"	"	1845

The mean or 7.8 divisions, equal to $3'.6$ of arc, has been adopted provisionally. Accordingly, all numbers in the printed record of observations, differing 7.8 scale divisions (or 10.3 divisions for June, and, up to July 18, 1840), from the mean monthly value at each hour of observation, were marked in pencil. It was found that the ratio of the disturbed observations to the total number was 1 : 9.6, or for

---

[1] In the first discussion of the Toronto observations for the years 1843, 1844, 1845, the limit of $3'.6$ was adopted, corresponding to one disturbance in every 13.6 observations; in the second discussion $5'.0$ was substituted as preferable. Phil. Trans., 1856, art. xv.

[2] Gould's Astronomical Journal, vol. iv., No. 83, 1855.

[3] A similar application was made in the discussion of Dr. E. K. Kane's magnetic observations at Van Rensselaer Harbor, North Greenland, by Mr. Schott. Smithsonian Contributions to Knowledge, vol. x., 1858.

the years 1843, 1844, 1845, 1 : 13.3 nearly (the years 1843 and 1845 being incomplete, and omissions only approximately allowed for). For comparison with the Toronto observations we have the ratio 1 : 9.4 for the series 1841 to 1848, inclusive,[1] and 1 : 13.6 for the series 1843, 1844, 1845,[2] both for the limit 3′.6, which was afterwards raised to 5′.0.[3] It was thought desirable in comparing these results, and especially as the Girard College observations do not extend either way to years of maximum of disturbance, which would otherwise require the enlargement of the limit, to preserve the limit as pointed out by the criterion; hence a deviation from the normal of 8.0 scale divisions as a convenient number, 3′.64 of arc, has been adopted for the present discussion as constituting a disturbed observation. Previous to July 18, 1840, the declinometer had a different scale, one division being 20″.7, making the corresponding limit for the first month and a half, 10.6 divisions.

All observations therefore differing 8.0 scale divisions from the mean monthly value of their respective hour were marked by a pencil line; a new hourly mean was taken, omitting values so marked, and each observation was again examined with reference to its deviation from this new mean. The process was repeated, when necessary, so that in all cases values differing $8^d.0$ or more from the final mean, were excluded. The last mean thus obtained for each observing hour and each month has been called "the normal." The following tables of normals present the mean monthly declinometer readings for each observing hour, free from all disturbances, deviating either way 3′.64 or more, from the normal position of the magnet for the respective hour, month, and year. The observations having been made at the even Göttingen hours, the local times are 19½ minutes after the even hour.[4] The time given in the tables is mean local time, counting from midnight, or 0^h up to 24^h.

Increase in the scale readings, corresponds to a decrease of westerly declination. The value of one division of scale is 0′.453.

---

[1] Observations made at the Magnetical and Meteorological Observatory at Toronto, in Canada, under the superintendence of Colonel Edward Sabine, vol. ii., 1843, 1844, 1845, with abstracts of observations to 1852, inclusive. London, 1853.

[2] Phil. Trans. R. S., 1851, art. v.

[3] Observations made at the Magnetical and Meteorological Observatory at Toronto, in Canada, under the superintendence of Major-General Edward Sabine, vol. iii., 1846, 1847, 1848, with abstracts of observations to 1855, inclusive. London, 1857.

[4] The observations were made at the even Göttingen time, $6^h\ 00^m$, corresponding to $0^h\ 19\frac{1}{2}^m$ of Philadelphia time.

TABLE I.—NORMALS OF THE DECLINOMETER READINGS FOR EACH OBSERVING HOUR AND MONTH, IN THE YEAR 1840.

Observations taken $19\frac{1}{2}$ minutes after the hour indicated.

Philadelphia mean time.	0h.	2h.	4h.	6h.	8h.	10h.	Noon.	14h.	16h.	18h.	20h.	22h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
June[1]	494.4	495.0	497.5	504.0	502.7	493.8	485.5	483.4	487.9	492.8	492.5	493.6
July	497.3	497.2	498.9	504.7	505.5	495.4	484.5	484.0	488.7	493.3	495.5	496.3
August	495.3	495.7	498.8	506.4	509.1	489.4	480.5	481.9	488.2	493.2	494.9	496.1
September[2]	492.5	495.2	496.9	503.2	502.5	490.8	477.3	479.5	488.4	489.9	493.3	492.6
October	492.5	490.4	491.1	489.1	489.2	484.1	478.4	477.3	481.9	486.3	485.9	493.1
November[3]	481.1	480.6	482.9	483.7	486.4	481.7	474.2	472.5	477.5	480.8	483.6	482.7
December	477.9	475.2	479.8	479.5	480.5	480.6	470.7	471.6	472.7	478.5	479.0	481.2
Mean	490.14	489.90	492.27	495.80	496.56	487.86	478.73	478.60	483.61	487.83	489.24	490.80
Correction[4]	+5.21	5.10	5.33	4.68	5.17	5.85	5.05	4.65	4.46	4.36	4.75	5.25
Mean for '40	495.35	495.00	497.60	500.48	501.73	493.71	483.78	483.25	488.07	492.19	493.99	496.05
Correction for index[5]	+93.30											
Cor. meau for 1840.	588.65	588.30	590.90	593.78	595.03	587.01	577.08	576.55	581.37	585.49	587.29	589.35

TABLE II.—NORMALS OF THE DECLINOMETER READINGS FOR 1841.

Value of 1 div. = 0′.453. Time $19\frac{1}{2}$ minutes later than indicated.

Philadelphia mean time.	0h.	2h.	4h.	6h.	8h.	10h.	Noon.	14h.	16h.	18h.	20h.	22h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
January	579.3	577.0	578.6	576.9	580.7	581.9	570.0	568.8	570.3	574.2	578.0	580.1
February	575.0	573.2	575.6	577.8	582.1	479.5	569.5	566.0	569.5	572.4	574.4	575.8
March	577.1	577.6	580.9	582.9	586.8	578.9	569.4	567.7	571.8	576.4	577.4	577.7
April	580.0	581.9	582.9	585.6	587.6	579.4	568.8	566.1	571.7	576.9	578.0	579.1
May	579.1	579.8	581.9	587.4	589.1	578.6	569.4	567.9	573.6	577.4	578.5	580.1
June	571.7	572.2	574.7	583.3	582.6	571.1	561.6	560.3	565.0	570.1	570.9	570.8
July	569.9	568.5	571.6	578.4	581.2	571.8	558.9	557.3	562.3	567.2	568.8	568.6
August	568.4	570.3	571.6	580.1	583.9	568.9	558.3	556.9	564.0	566.8	568.6	568.9
September	565.1	564.5	565.5	569.4	571.1	564.1	553.6	554.5	559.5	562.9	563.8	564.0
October	566.8	566.3	565.5	567.6	569.4	568.2	564.0	562.3	564.7	573.5	568.6	569.3
November	557.2	558.5	558.5	557.6	561.7	557.1	551.8	549.9	553.4	554.9	558.0	558.6
December	560.1	559.3	560.5	559.6	560.1	558.1	552.9	551.7	555.8	559.6	563.3	561.6
Mean	570.81	570.76	572.32	575.55	578.03	571.47	562.35	560.78	565.13	569.36	570.70	571.22

[1] The readings from June 1st to July 18th, 15 hours, on the College building scale, were converted into observatory scale readings by subtracting $144^{d}.7$ at division 628.8 of the old scale, and converting the value of a division 0′.345 of the old into the corresponding reading for the value of a division 0′.453 of the new scale. The mean readings, thus corrected, of the first 18 days of July were then properly combined with the mean of the remaining days of the month.

[2] In the month of September, hour 8, the comparisons were made with the half monthly means, owing to the rapid change of the readings.

[3] On the 23d of November the index of the declinometer bar shifted 19.5 scale divisions; a correction of $+19^{d}.5$ has, therefore, been added to observations after this date, and, likewise, to all the readings of the following month.

[4] The corrections here given for referring the mean of the last seven months of the year to the mean for the whole year, are derived from the normals of the following year 1841 by comparing the mean of the same seven months with the annual mean of that year. Comparing the same months in the two years the character of the changes appears to be about the same.

[5] A further correction for change in the zero of the scale required to refer the readings of 1840 to the readings of subsequent years. Owing to a rearrangement of the instruments on January 7, 1841, the scale readings changed 112.8 divisions, and since 19.5 scale divisions had been added to the December readings, the resulting correction is the difference of the two, or $+93^{d}.30$.

In general during the year 1841 the readings are more changeable than during the following years.

The rearrangement of the instruments, and consequent shifting of the index of the scale, alluded to in the preceding notes, interrupted the observations between January 1 and January 12.

The normal for October, 14^h, was obtained by comparing with the half monthly means and taking the mean of the two results as in a similar case for the month of September of the previous year.

TABLE III.—NORMALS OF THE DECLINOMETER READINGS FOR 1842.

Value of 1 div. = 0′.453. Time $19\frac{1}{2}$ minutes later than indicated.

Philadelphia mean time.	0h.	2h.	4h.	6h.	8h.	10h.	Noon.	14h.	16h.	18h.	20h.	22h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
January	564.3	563.8	565.3	565.9	570.9	566.4	556.7	556.0	562.9	563.2	566.1	567.8
February	564.5	564.3	563.8	565.2	567.8	565.5	558.2	559.9	558.0	561.9	565.3	565.5
March	564.8	564.1	565.4	566.1	571.8	565.9	555.6	553.9	556.4	560.3	564.5	564.9
April	563.3	565.4	566.1	568.5	569.7	563.6	554.0	552.5	555.1	560.6	561.3	563.0
May	563.3	564.3	566.0	571.2	569.5	560.0	552.6	552.3	557.7	560.8	561.8	562.3
June	564.6	563.7	567.2	573.7	573.0	565.2	555.1	552.5	558.3	561.8	563.7	564.1
July	566.0	566.0	568.4	576.6	576.4	565.8	556.3	553.8	558.5	562.4	564.2	567.1
August	564 8	566.0	568.5	573.7	575.0	560.0	552.3	553.7	561.5	562.2	564.1	564.5
September	567.4	567.8	570.0	576.8	574.9	561.2	556.0	555.4	562.0	565.7	566.7	566.6
October	563.1	563.1	564.4	566.0	568.8	564.0	556.0	555.0	558.2	564.3	565.0	565.3
November	564.2	563.8	565.6	566.9	569.2	563.3	556.6	557.3	561.2	564.0	565.5	565.0
December	561.7	560.7	562.1	562.7	565.5	564.2	556.6	556.2	560.1	562.0	563.5	563.8
Mean	564.33	564.42	566.07	569.44	571.04	563.76	555.50	554.54	559.16	562.42	564.31	564.99

TABLE IV.—NORMALS OF THE DECLINOMETER READINGS FOR 1843.

Value of 1 div. = 0′.453. Time $19\frac{1}{2}$ minutes later than indicated.

Philadelphia mean time.	0h.	2h.	4h.	6h.	8h.	10h.	Noon.	14h.	16h.	18h.	20h.	22h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
January	...	...	...	...	...	...	...	555.4	...	...	...	...
February	...	...	...	...	...	...	...	555.9	...	...	...	...
March	...	...	...	...	...	...	...	557.2	...	...	...	...
April	569.7	570.0	571.0	574.7	576.2	566.2	557.8	555.7	562.6	564.8	568.5	568.7
May	567.0	567.3	569.6	574.6	575.6	565.7	556.0	556.2	562.2	566.4	566.9	567.3
June	566.0	565.6	568.4	574.1	573.9	564.8	556.4	556.0	561.1	564.3	564.0	565.6
July	566.9	565.9	568.2	574.2	574.6	564.5	555.1	554.1	559.5	563.6	563.8	565.6
August[1]	564.2	564.5	567.2	573.5	572.7	560.5	555.1	554.6	561.2	563.6	562.3	564.2
September	560.4	560.4	560.3	565.7	566.6	554.6	547.5	550.5	556.8	558.0	560.0	558.7
October	559.6	559.6	559.9	562.1	566.0	560.8	553.6	552.7	556.2	558.2	560.1	559.7
November	556.3	556.6	557.4	559.1	561.3	556.2	550.4	551.1	553.8	556.3	557.5	557.3
December	559.0	557.4	557.8	560.0	561.2	559.9	552.9	550.9	554.6	558.2	559.6	559.9
Mean	563.23	563.03	564.42	568.67	569.79	561.47	553.42	554.19	558.67	561.50	562.52	563.00
Correction[2]	+0.06	—0.11	—0.41	—1.24	—0.30	+0.63	+0.44	...	—0.02	—0.23	+0.33	+0.35
Cor'd mean	563.29	562.92	564.01	567.43	569.49	562.10	553.86	554.19	558.65	561.27	562.85	563.35

[1] The suspension threads of the declinometer gave way on the 9th of August, and again on the 10th of January, 1844, but after readjusting the instruments, the magnet returned almost exactly to its former reading—a mean of the two changes gave as a correction +18.7 divisions, which was accordingly added to all the readings of the year after August 9th, 21 hours.

[2] The correction to refer the mean of the nine last months to the mean of all the months is derived from the readings of the preceding year, as being more uniform in character than those for the year following.

The hourly readings commence on October 1, and are continued to the close of the series.

To make the readings of the odd hours of the months of October, November, and December comparable with those of the even hours during the whole year, the means of the even hours for the months of October, November, and December (1843) were compared with the corrected annual means respectively, which gave the corrections for the even hours; and the corrections for intermediate odd hours were obtained from those of the nearest even hours. The deductions from the series of observations at odd hours have but one-third of the weight of those obtained from the even series.

TABLE IV. (*b*).—ADDITIONAL NORMALS FOR THE ODD HOURS OF THE MONTHS OF OCTOBER, NOVEMBER, AND DECEMBER, 1843.

Value of 1 div. = 0′.453. Time $19\frac{1}{2}$ minutes later than indicated.

Philadelphia mean time.	1h.	3h.	5h.	7h.	9h.	11h.	13h.	15h.	17h.	19h.	21h.	23h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
October	560.2	559.1	560.6	565.1	565.0	556.5	552.6	554.2	557.0	559.7	561.1	560.7
November	556.7	556.6	557.4	561.8	560.1	552.6	550.0	552.6	554.9	557.5	557.7	557.4
December	558.1	558.2	558.8	560.8	561.9	556.7	551.4	553.1	557.5	558.9	560.0	559.5
Mean	558.33	557.97	558.93	562.57	562.33	555.27	551.33	553.30	556.47	558.70	559.60	559.20
Correction	+5.01	+5.37	+6.36	+6.84	+4.92	+2.37	+2.09	+3.20	+3.74	+3.74	+4.08	+4.70
Cor'd mean	563.34	563.34	565.29	569.41	567.25	557.64	553.42	556.50	560.21	562.44	563.68	563.90

TABLE V.—NORMALS OF THE DECLINOMETER READINGS FOR 1844.

Value of 1 div. = 0′.453. Time $19\frac{1}{2}$ minutes later than indicated.

Philadelphia mean time.	0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
January	558.6	558.2	558.4	559.2	558.9	558.8	559.7	561.2	562.9	563.3	559.1	555.9
February	559.1	558.5	559.1	559.2	559.9	561.1	560.8	562.1	562.2	560.7	557.3	554.5
March	558.0	559.0	559.2	557.9	559.8	560.2	561.3	563.6	564.8	564.1	560.3	554.9
April	556.6	557.0	557.2	556.9	557.5	558.4	561.7	558.5	564.4	561.8	557.1	552.0
May	548.4	548.7	547.8	547.0	549.3	552.5	555.8	556.8	555.1	552.3	546.7	542.2
June	548.7	549.0	549.3	549.1	551.6	553.9	557.6	559.1	558.2	554.3	547.9	541.8
July	549.0	550.5	548.4	549.4	551.0	554.3	556.9	559.8	558.6	554.8	548.0	540.8
August	548.6	547.8	547.3	547.4	550.9	552.4	557.5	560.3	558.2	551.8	543.3	536.4
September	543.3	543.1	544.1	546.0	546.5	547.1	550.0	552.9	552.4	545.8	538.3	532.5
October	545.1	545.3	544.2	546.1	545.8	544.4	548.6	550.9	551.5	548.7	545.3	540.8
November	546.8	546.8	548.3	548.6	547.4	548.5	551.5	549.2	548.4	547.9	546.2	542.8
December	536.1	535.8	535.4	535.9	536.8	537.3	537.2	536.8	537.9	539.3	536.1	532.9
Mean	549.86	549.98	549.89	550.23	551.28	552.41	554.88	555.93	556.22	553.73	548.80	543.96

Philadelphia mean time.	Noon.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.
	d.	d.	d	d.	d.	d.	d	d.	d.	d.	d.	d.
January	552.9	552.4	553.2	554.1	556.3	556.9	557.8	559.2	559.5	560.9	560.8	559.6
February	551.1	551.1	553.0	554.7	556.4	556.6	557.6	558.4	559.9	559.4	560.1	559.0
March	550.6	549.4	549.6	551.7	553.0	555.2	556.6	558.0	558.4	558.2	558.6	559.7
April	547.4	545.7	546.2	547.6	549.6	553.4	553.4	553.8	556.2	555.1	555.7	559.3
May	538.3	535.8	536.5	538.9	542.1	545.1	545.2	546.5	546.3	547.3	547.3	547.8
June	537.4	535.0	537.3	540.0	542.4	545.2	545.6	546.2	546.5	546.8	548.0	548.5
July	538.3	535.5	536.3	538.8	541.9	544.5	545.8	546.2	546.6	547.4	548.8	549.3
August	531.8	532.0	534.3	538.7	542.1	544.3	546.0	546.5	546.7	546.6	547.8	547.7
September	529.3	530.0	534.1	538.3	539.4	541.9	542.4	541.9	543.0	544.6	543.7	543.3
October	541.1	539.5	541.4	544.0	545.7	545.4	545.6	545.0	544.9	544.6	544.5	544.6
November	542.8	541.7	544.5	546.1	545.6	547.9	548.8	548.2	548.3	549.6	548.0	548.0
December	530.6	529.3	529.4	532.1	533.2	534.8	535.9	537.0	536.8	537.4	537.8	537.1
Mean	540.97	539.78	541.32	543.75	545.64	547.60	548.44	548.91	549.43	549.83	550.10	550.33

To the observations between January 1 and January 10 a correction of $+18^{d}.7$ was applied, as explained in the preceding note.

In the month of December the declination changed so rapidly as to require the use of half monthly means; the mean of the two results is inserted in the above table.

TABLE VI.—NORMALS OF THE DECLINOMETER READINGS FOR 1845.

Value of 1 div. = 0′.453. Time $19\frac{1}{2}$ minutes later than indicated.

Philadelphia mean time.	0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
January	530.9	531.3	531.1	531.5	533.0	531.6	532.9	535.2	535.8	533.8	530.2	526.7
February	531.6	531.1	531.0	532.4	532.3	533.1	534.7	535.9	535.7	535.4	533.0	528.6
March	532.9	532.7	533.7	533.6	535.0	533.9	536.0	538.8	539.4	538.6	534.5	529.4
April	529.1	528.8	529.0	529.2	529.8	531.7	534.0	535.6	537.5	535.4	528.5	522.5
May	529.9	531.3	529.7	531.7	533.2	536.3	539.3	541.9	540.7	536.0	528.0	522.6
June	531.5	531.7	531.6	532.0	534.8	537.9	541.9	543.5	542.5	538.6	532.2	524.9
Mean	530.98	531.15	531.02	531.73	533.02	534.08	536.47	538.48	538.60	536.30	531.07	525.78
Correction[1]	—2.42	—2.50	—2.58	—2.41	—2.26	—2.03	—1.81	—2.01	—2.21	—2.76	—3.30	—2.94
Cor'd mean	528.56	528.65	528.44	529.32	530.76	532.05	534.66	536.47	536.39	533.54	527.77	522.84
Philadelphia mean time.	Noon.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.
	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.	d.
January	524.2	525.2	526.2	528.0	530.1	531.8	532.7	532.8	533.3	533.0	532.4	532.0
February	524.4	523.0	525.3	527.5	529.7	530.4	532.4	531.3	533.6	534.4	532.3	531.9
March	524.8	522.5	522.8	524.8	527.8	529.7	531.6	533.0	533.0	533.8	533.5	534.0
April	517.8	513.9	514.0	517.2	521.5	525.8	527.8	527.9	528.1	528.5	528.0	529.4
May	517.1	516.8	518.9	522.1	526.7	529.3	529.6	530.4	529.7	530.3	530.5	530.3
June	521.3	519.6	520.0	522.1	525.4	528.9	530.3	530.7	530.1	530.7	530.3	531.4
Mean	521.60	520.17	521.20	523.62	526.87	529.32	530.73	531.02	531.30	531.78	531.17	531.50
Correction[1]	—2.59	—2.28	—1.98	—1.80	—1.62	—1.64	—1.65	—1.99	—2.23	—2.36	—2.47	—2.44
Cor'd mean	519.01	517.89	519.22	521.82	525.25	527.68	529.08	529.03	529.07	529.42	528.70	529.06

For the purpose of comparing the annual means of the normals, or the mean march of the regular solar-diurnal variation for each year, the preceding results have been expressed analytically by means of Bessel's formula, and by the application of the method of least squares.

In these formulæ the angle θ is reckoned from midnight (Philadelphia), at the rate of 15° for each following hour. It was found unnecessary to carry the expressions beyond the third term, the fourth being generally smaller than the probable error of an hourly normal. We obtain accordingly—

For 1840 $D = 586^{d}\ 73 + 6^{d}.214 \sin(\theta + 36° 35') + 4^{d}.588 \sin(2\theta + 217° 33') + 1^{d}.640 \sin(3\theta + 68° 50')$

" 1841 $D = 569.87 + 4.888 \sin(\theta + 30\ \ 05) + 4.380 \sin(2\theta + 212\ \ 38) + 1.581 \sin(3\theta + 50\ \ 14)$

" 1842 $D = 563.33 + 4.944 \sin(\theta + 33\ \ 49) + 4.211 \sin(2\theta + 217\ \ 12) + 1.463 \sin(3\theta + 64\ \ 42)$

" 1843 $D = 562.01 + 4.449 \sin(\theta + 36\ \ 00) + 3.918 \sin(2\theta + 218\ \ 05) + 1.811 \sin(3\theta + 68\ \ 18)$

" 1844 $D = 548.89 + 4.486 \sin(\theta + 34\ \ 35) + 3.872 \sin(2\theta + 222\ \ 23) + 1.802 \sin(3\theta + 68\ \ 53)$

" 1845 $D = 528.12 + 4.548 \sin(\theta + 35\ \ 33) + 4.872 \sin(2\theta + 225\ \ 35) + 1.987 \sin(3\theta + 61\ \ 20)$

---

[1] As indicated by the annual change in the readings, it was considered preferable to obtain the annual mean by deducing the correction to the mean of the first six months, from the readings of the preceding year and those of the year 1842.

Owing probably to the several accidental changes in the suspension of the bar, and consequent uncertainty in the precise amount of scale correction, the mean readings of each year, when compared with one another, exhibit differences not actually due to inequalities occasioned by declination changes. This question, however, does not directly bear upon the present investigation, which mainly depends on differences of readings, and it is proper to remark that the observed increase, giving the weight one-half to the mean of 1840 and of 1845, is under the supposition of a uniform annual change between these years, equal to 4′.50. From Mr. Schott's investigation[1] of the secular change of the declination at Philadelphia, supported by observations between the years 1701 and 1855, the annual increase between the years 1840 and 1845 is 4′.98, a result which accords tolerably well with actual observations. According to his formula, the declination on the first of January, 1843, the mean epoch of the present series was 3° 32′ west, with a probable error of $\pm$ 10′, which corresponds to the scale reading 560.31, deduced by taking into account the weights of the annual means.

We now proceed to the investigation of the inequality in the diurnal variation, changing the preceding formulæ for greater convenience into the following:—

For 1840 $\Delta = +2'.815 \sin(15^\circ n + 36^\circ 35') + 2'.078 \sin(30^\circ n + 217^\circ 33') + 0'.743 \sin(45^\circ n + 68^\circ 50')$
" 1841 $\Delta = +2.214 \sin(15\ n + 30\ 05) + 1.984 \sin(30\ n + 212\ 38) + 0.716 \sin(45\ n + 50\ 14)$
" 1842 $\Delta = +2.240 \sin(15\ n + 33\ 49) + 1.908 \sin(30\ n + 217\ 12) + 0.663 \sin(45\ n + 64\ 42)$
" 1843 $\Delta = +2.015 \sin(15\ n + 36\ 00) + 1.775 \sin(30\ n + 218\ 05) + 0.820 \sin(45\ n + 68\ 18)$
" 1844 $\Delta = +2.032 \sin(15\ n + 34\ 35) + 1.754 \sin(30\ n + 222\ 23) + 0.816 \sin(45\ n + 68\ 53)$
" 1845 $\Delta = +2.060 \sin(15\ n + 35\ 33) + 2.206 \sin(30\ n + 225\ 35) + 0.900 \sin(45\ n + 61\ 20)$

Where Δ = the regular solar-diurnal variation.
n = the number of hours after midnight.

To show the agreement between these expressions and the corresponding observed quantities, and to exhibit to the eye the character of the diurnal variation, the results have been thrown into curves. The observed bi-hourly means are represented in Fig. 2 (p. 11) by dots, and in no instance do they differ from the computed values by as much as $0^d.8$ or 0′.3. As a specimen of the representation, I add the results for the year 1845:—

Hour.	Observed value.	Computed value.	C—O.	Hour.	Observed value.	Computed value.	C—O.
h. m.	d.	d.	d.	h. m.	d.	d.	d.
0 19½	528.56	528.99	+.43	12 19½	519.01	519.23	+.22
2 19½	528.44	528.48	+.04	14 19½	519.22	518.96	—.26
4 19½	530.76	530.26	—.50	16 19½	525.25	525.18	—.07
6 19½	534.66	535.11	+.45	18 19½	529.08	529.15	+.07
8 19½	536.39	535.97	—.42	20 19½	529.07	529.07	.00
10 19½	527.77	528.18	+.41	22 19½	528.70	528.86	+.16

The average probable error of any single representation by the formula is $\pm 0^d.22$ or $\pm 0'.10$.

By means of the preceding formulæ the following values were computed: 1. The time when the north end of the magnet reached its extreme eastern position, or, in other words, the epoch of the eastern elongation. 2. The corresponding maximum scale reading, or, more properly, the corresponding minimum of western declination. 3. The time of the occurrence of the western elongation; and 4. The corresponding

[1] Report on the progress of the U. S. Coast Survey for 1855, Appendix, No. 48, and an Appendix (p. 11) of the report for 1859.

maximum reading of western declination. In the last two columns the difference of the scale readings, or the amplitude of eastern and western elongation, is made out in scale divisions, and also in minutes of arc.

The inequality of this amplitude next requires our attention.

For	Epoch of eastern deflection.	Corresponding scale reading.	Epoch of western deflection.	Corresponding scale reading.	Amplitude.	
	h. m.	d.	h. m.	d.	d.	′
1840	7 26 A. M.	595.67	1 34 P. M.	575.71	19.96	9.08
1841	7 49	577.96	1 49	560.21	17.75	8.06
1842	7 36	571.24	1 37	553.96	17.28	7.83
1843	7 40	569.54	1 24	553.06	16.48	7.46
1844	7 32	556.50	1 18	539.99	16.51	7.51
1845	7 34	536.65	1 16	517.81	18.84	8.53
Mean	7 36 A. M. ±3		1 30 P. M. ±4			

The inequality constituting the ten or eleven year period is plainly exhibited in the last two columns of the above table, the progression in the numbers being quite regular. The year 1843 is clearly indicated as the year of the minimum range of the diurnal fluctuation, but whether the period is one nearer to ten or to eleven years cannot be decided from the Girard College observations, since they do not embrace a year of maximum amplitude. The epoch of the minimum, however, can be determined with more precision. For this purpose only, the values in the last column are represented by the formula,

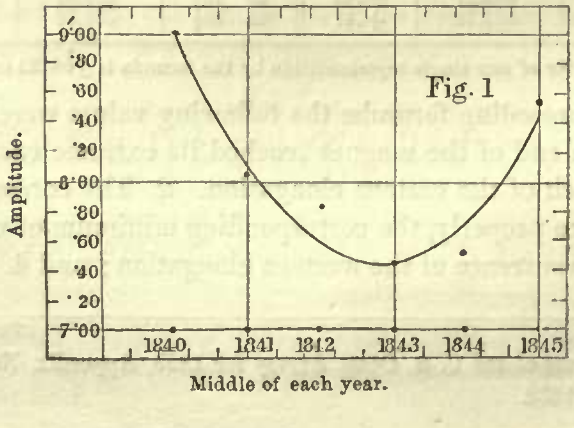
$$A = 9'.08 - 1'.14\,(t - 1840.5) + 0'.201\,(t - 1840.5)^2,$$

deduced by the method of least squares, and the quantities come out as follows:—

Year.	Observed amplitude.	Computed by formula.	Difference.	Year.	Observed amplitude.	Computed by formula.	Difference.
1840.5	9′.08	9′.08	0′.00	1843.5	7′.46	7′.47	—0′.01
1841.5	8.06	8.14	—0.08	1844.5	7.51	7.74	—0.23
1842.5	7.83	7.60	+0.23	1845.5	8.53	8.41	+0.12

Probable error of any single amplitude, ±0′.11.

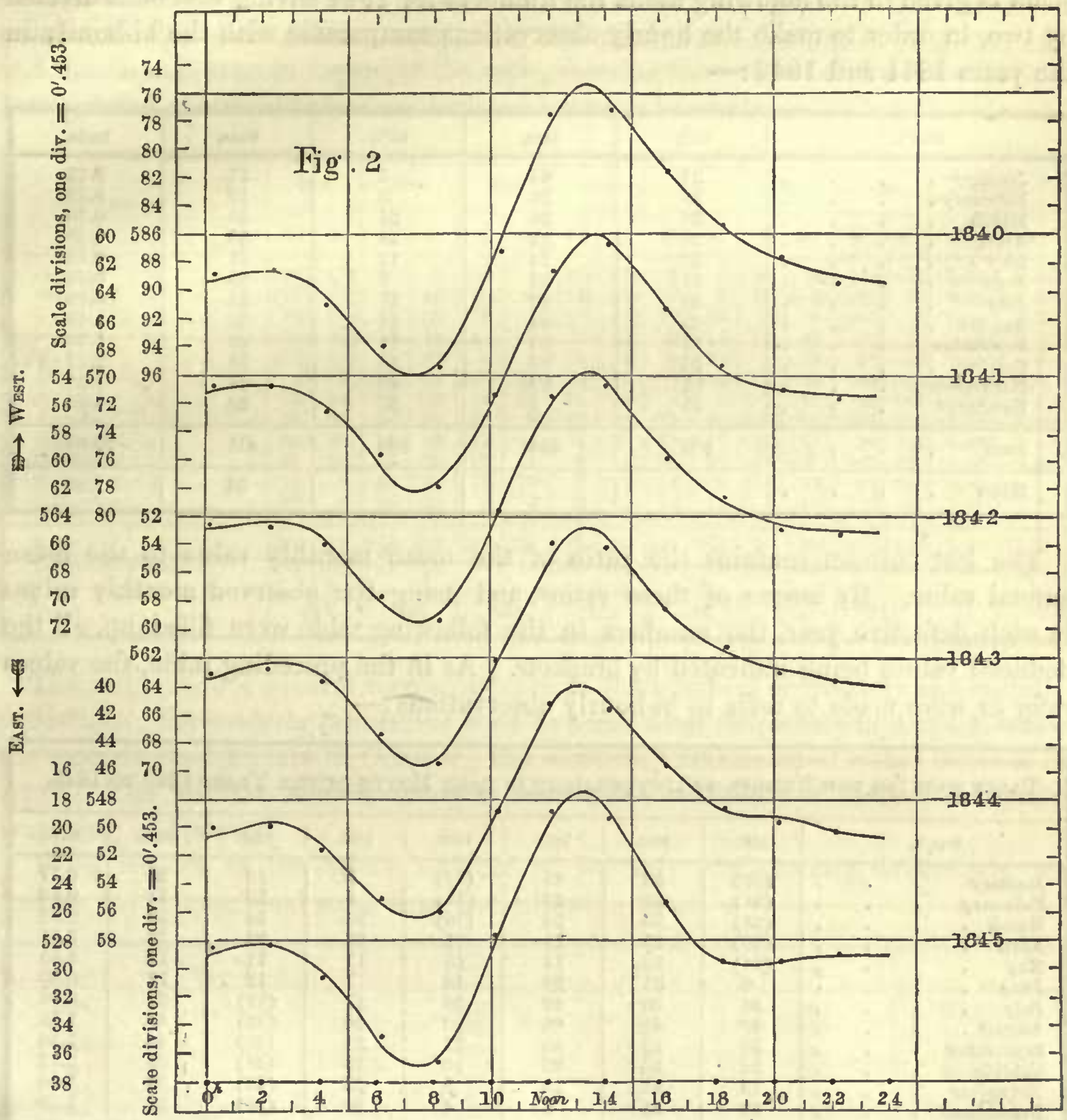
That portion of the ten or eleven year period which results from the preceding discussion of the differential observations of the magnetic declination, free from the effect of the disturbances as far as the latter can be eliminated, is shown graphically in Fig. 1.



Middle of each year.

The month of May, in the year 1843, is indicated by the formula as the epoch of the minimum amplitude.

REGULAR SOLAR-DIURNAL VARIATION OF THE DECLINATION.



We now proceed to the discussion of the disturbances as far as they bear on the decennial inequality, taking in also some collateral results.

The total number of observations for changes of declination recorded and discussed amounts to 24,566; of these, 2357 were separated as disturbances differing eight scale divisions or more from their respective normals, leaving 22,209 observations, from which the preceding results were deduced. There is one disturbed observation in every 10.4 observations.

The discussion of the disturbances divides itself into two parts, that of the number and that of the amount of the larger deflections.

Owing to partial incompleteness in the number of observing months in some years, it became necessary to fill out the number for the annual inequality from the results of the complete years. Their number for each month in the complete years is given in the following table, the numbers for 1844 having first been divided by two, in order to make the hourly observations comparable with the bi-hourly in the years 1841 and 1842:—

Month.	1841.	1842.	1844.	Mean.	Ratio.
January	33	44	5	27	0.75
February	25	26	5	19	0.53
March	26	24	24	25	0.70
April	25	31	39	32	0.89
May	33	14	17	21	0.58
June	31	30	7	23	0.64
July	30	40	15	28	0.78
August	49	64	44	52	1.45
September . . .	57	60	31	49	1.36
October	94	86	53	78	2.17
November . . .	81	22	42	48	1.33
December . . .	55	5	26	29	0.82
Sum	539	446	308	431	12.00
Mean				36	1.00

The last column contains the ratio of the mean monthly value to the mean annual value. By means of these ratios, and using the observed monthly values in each defective year, the numbers in the following table were filled up, all the deduced values being indicated by brackets. As in the preceding table, the values refer or were made to refer to bi-hourly observations:—

TABLE SHOWING THE NUMBER OF DISTURBANCES IN EACH MONTH OF THE YEARS 1840 TO 1845.

Month.	1840.	1841.	1842.	1843.	1844.	1845.	Mean.	Ratio.
January . . .	(30)	33	44	(17)	5	19	25	0.77
February . . .	(21)	25	26	(12)	5	13	17	0.52
March	(28)	26	24	(16)	24	14	22	0.68
April	(36)	25	31	21	39	22	29	0.91
May	(24)	33	14	15	17	11	19	0.58
June	8	31	30	12	7	12	17	0.53
July	44	30	40	20	15	(17)	28	0.86
August	40	49	64	80	44	(32)	51	1.59
September . . .	56	57	60	27	31	(30)	44	1.36
October . . .	94	94	86	16	53	(48)	68	2.12
November . . .	19	81	22	8	42	(28)	35	1.08
December . . .	83	55	5	4	26	(18)	32	1.00
Sum	344	539	446	230	308	91	387	12.00
Corrected sum and mean	483			275		264	32	1.00

The ratios in the last column show the annual inequality in the distribution of the disturbances. The principal maximum occurs in October,[1] the secondary in April; the two minima, nearly of equal amount, occur in the months of February and June. The progression of the numbers is regular.

---

[1] At Toronto this maximum occurred in September; the first minimum is likewise one month earlier at this station than at Philadelphia.

If we separate the numbers in accordance with westerly and easterly deflections we obtain the following table, deduced as in the former case. It may be remarked that on account of the separate ratios used for the interpolation of the western and eastern deflections, their sum in any one month does not give the corresponding number in the above table exactly, only the yearly sums having been preserved; and the same is true in regard to the table, showing the amount of the disturbances. Interpolated values as before are inclosed between brackets:—

Month.	1840.		1841.		1842.		1843.		1844.		1845.		Sums.		Ratios.	
	W.	E.	W.	E.	W.	E.	W.	E.	W.	E.	W.	E.	W.	E.	W.	E.
January	(36)	(2)	25	8	35	9	(22)	(7)	2	3	10	9	130	38	1.27	0.42
February	(17)	(3)	9	16	17	9	(13)	(9)	3	2	11	2	70	41	0.70	0.46
March	(23)	(5)	11	15	17	7	(15)	(6)	10	14	9	5	85	52	0.83	0.57
April	(27)	(5)	10	15	14	17	7	14	25	14	15	7	98	72	0.95	0.80
May	(17)	(4)	18	15	8	6	7	8	4	13	3	8	57	54	0.55	0.60
June	3	5	15	16	17	13	2	10	3	4	5	7	45	55	0.44	0.61
July	17	27	5	25	14	26	11	9	6	9	(7)	(11)	60	107	0.58	1.18
August	20	20	18	31	55	9	67	13	25	19	(20)	(11)	205	103	2.00	1.14
September	36	20	14	43	11	49	6	21	18	13	(11)	(21)	96	167	0.93	1.86
October	68	26	34	60	17	69	6	10	23	30	(15)	(30)	163	225	1.58	2.50
November	11	8	41	40	11	11	5	3	16	26	(15)	(14)	99	102	0.96	1.12
December	77	6	24	31	1	4	2	2	12	14	(8)	(10)	124	67	1.21	0.74
Sum	232	112	224	315	217	229	113	90	147	161	53	38	1232	1083	12.00	12.00
Corrected mean . .	352	131	...	...	...	...	163	112	...	...	129	135	...	...	...	...
Total	483		539		446		275		308		264		2315		...	

The ratios show a general correspondence in the numbers of westerly and easterly deflections; the westerly deflections seem to occur most frequently in August, while the easterly predominate in October; the secondary maximum of either series is in April. The minima remain nearly as before, one minimum of eastern deflection occurring in January.

With respect to the whole number of westerly and easterly deflections, we deduce the proportional sums from the following table:—

Year.	W.	E.	Sum.	
1840	352	131	483	Weight ½
1841	224	315	539	
1842	217	229	446	
1843	163	112	275	Weight ⅔
1844	147	161	308	
1845	129	135	264	Weight ½
Sum	1232	1083	2315	
Proportional sums by weight .	937	912		

On account of the incompleteness of the record in the years 1840, 1843, and 1845, the number of eastern and western disturbances relative to the total number cannot be ascertained with accuracy. They are about equal in the record. At Toronto the eastern predominate over the western in the proportion of 1.17 to 1 (for the years 1841 to 1848), and nearly to the same extent for each year, taken separately.

The numbers in the column headed "sum" do not indicate the law of the eleven

year period as plainly and systematically as did the investigation of the diurnal amplitude; yet giving half weight, on account of the want of record, to the sums for 1840 and 1845, the minimum number falls in the year 1843. More consistent results would, no doubt, have been obtained if the year 1845 had been complete.

If we distribute the disturbances (1942 in number for the even hours) according to their respective hours of occurrence, the following table results from observations between 1840 and 1845:—

Add 19½ m.	W.	E.	Sum.	Ratios.		Add 19½ m.	W.	E.	Sum.	Ratios.	
				W.	E.					W.	E.
0h.	67	95	162	0.82	1.20	Noon	93	57	150	1.13	0.71
2	97	92	189*	1.18	1.16	14h.	79	54*	133*	0.95	0.67*
4	89	79	168	1.08	0.96	16	88	60	148	1.07	0.78
6	110*	63	173	1.35*	0.80	18	72	71	143	0.87	0.90
8	105	56	161	1.29	0.70	20	34*	133*	167	0.40*	1.66*
10	107	71	178	1.32	0.88	22	45	125	170	0.54	1.58

Maxima and minima values are distinguished by an asterisk.

The numbers in each vertical column show a regular progression; and the number of disturbances, irrespective of their direction, have a minimum at 2 P. M. and a maximum at 2 A. M.[1] The principal contrast is between the hours of the day and the hours of the night; in the former case the numbers being below, but in the latter above the mean value. This is in close correspondence with the Toronto results. The most striking result of the above table is—that the westerly disturbances have their minimum precisely at the hour (8 P. M.) when the easterly have their maximum value; and the exact coincidence of this result with that deduced by General Sabine for Toronto is not less remarkable. For the westerly disturbances, the hours 6 A. M. (maximum) and 8 P. M. (minimum), and for the easterly disturbances the hours 2 P. M. (minimum) and 8 P. M. (maximum), are specially contrasted. These results also agree with those found at Toronto; and the accordance with that station even goes so far as to exhibit the secondary minimum of eastern disturbances at 8 A. M. In connection with this subject it may be here stated, that the same distinguished magnetist found a singular mutual relation to subsist between the phenomena at Toronto and Point Barrow, on the shores of the Arctic Sea—the laws of the easterly deflection at one station being found to correspond for the same local hours, with those of the westerly deflections at the other station, and *vice versâ*. This contrast holds good for Philadelphia as well as for Toronto.

We now pass to the consideration of the amount of deflections caused by the disturbances, classifying the same according to years, months, and hours:—

[1] At Toronto the respective hours are 2 P. M. and 22 P. M.

AGGREGATE VALUES OF THE DISTURBANCES, AND MEAN VALUES IN THE DIFFERENT YEARS.

Year.	Aggregate values.	Same corrected to 12 months.	Number.	Average value of a disturbance.	Same in minutes of arc.	Same at Toronto for comparison.
	d.	d.		d.	′	′
1840	5140.0 (7 months)	7155.5	483	14.8	6.70	...
1841	7844.4	7844.4	539	14.6	6.61	6.34
1842	6019.1	6019.1	446	13.5	6.11	5.90
1843	2465.7 (9 months)	2932.2	275	10.7	4.85	5.62
1844	4227.3	4227.3	308	13.7	6.21	6.49
1845	1138.6 (6 months)	3521.4	264	13.3	6.02	5.84

The table includes only the series of bi-hourly observations; the reduction of the numbers from incomplete years to the correct sum for the whole year being effected by means of ratios as in the discussion of the number of disturbances. For comparison the average value of a disturbance at Toronto is added. It must be remarked, that the amount of deviation from the normal, constituting a disturbance, was nearly but not quite the same at Toronto as at Philadelphia, so that the ratios of the corresponding numbers in the last two columns should be compared.

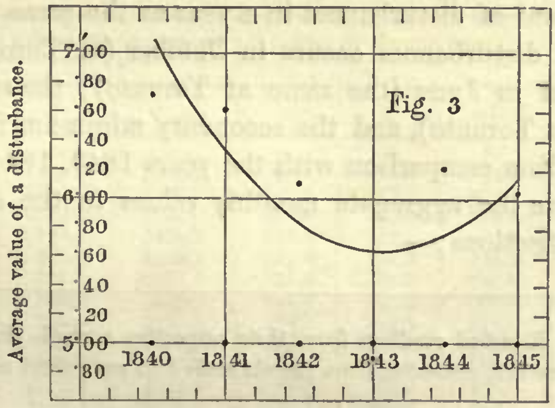
The eleven year period is well marked in the aggregate value of the disturbances, as well as in their average value in the different years; and the year 1843 is decidedly indicated as the minimum. To find a more precise value for the epoch of the minimum, the formula,

$$\delta = 7'.09 - 0'.930\,(t - 1840.5) + 0'.149\,(t - 1840.5)^2,$$

has been constructed, which represents the observed values as follows:—

Year.	Observed amount.	Computed amount.	Difference.	Year.	Observed amount.	Computed amount.	Difference.
1840.5	6′.70	7′.09	+0′.39	1843.5	4′.85	5′.64	+0′.79
1841.5	6.61	6.31	—0.30	1844.5	6.21	5.75	—0.46
1842.5	6.11	5.83	—0.28	1845.5	6.02	6.16	+0.14

The first and last value have only half weight. According to the formula, the minimum took place in August, 1843. (See Fig. 3.)



(Middle of each year.)

As the resulting epoch from the differential observations with the declinometer we find the month of June, 1843, by giving double weight to the result deduced from the inequality of the diurnal amplitude.

Separating into western and eastern disturbances we find—

Year.	West Deflections.			East Deflections.		
	Aggregate value.	n	Average value.	Aggregate value.	n	Average value
	d.		′	d.		′
1840 . . .	5064.8	352	6.52	2090.7	131	7.20
1841 . . .	2935.5	224	5.93	4908.9	315	7.07
1842 . . .	2645.9	217	5.53	3373.2	229	6.70
1843 . . .	1741.6	163	4.85	1190.6	112	4.85
1844 . . .	2019.7	147	6.21	2207.6	161	6.21
1845 . . .	1489.2	129	5.25	2032.3	135	6.84

From which it appears that the easterly values preponderate over the westerly in the ratio of 1.14 to 1. The ratio from the Toronto observations between 1844 and 1848 is 1.28 to 1.

The following table shows the aggregate amount of disturbances in each month of the different years, or the annual inequality of the aggregate disturbances:—

Month.	1840.	1841.	1842.	1843.	1844.	1845.	Mean.	Ratio.
	d.	d.	d.	d.	d.	d.	d.	
January . . .	(418.4)	423.6	585.9	(171.0)	45.3	269.2	318.9	0.72
February . .	(323.0)	402.3	310.1	(131.9)	99.7	160.1	237.8	0.54
March . . .	(400.5)	327.9	264.4	(163.6)	430.0	167.4	292.3	0.66
April	(544.6)	294.7	481.1	281.7	601.5	289.7	415.6	0.94
May	(329.0)	442.8	184.4	206.8	205.5	111.0	246.6	0.56
June	83.1[1]	355.5	353.1	133.9	50.4	141.2	186.2	0.42
July	668.8[1]	416.8	546.8	271.5	168.3	(220.4)	382.1	0.87
August . . .	618.6	823.1	873.5	953.9	552.6	(434.2)	709.3	1.61
September . .	853.5	1242.7	779.9	301.5	448.6	(484.1)	685.0	1.56
October . . .	1319.1	1376.2	1253.2	195.0	668.1	(639.3)	908.5	2.06
November . .	314.6	1054.2	339.3	87.1	591.1	(387.4)	462.3	1.06
December . .	1282.3	684.6	47.4	34.3	366.2	(217.4)	438.7	1.00
Sum	7155.5	7844.4	6019.1	2932.2	4227.3	3521.4	5283.3	12.00

The last column of ratios of the aggregate value of the disturbances of each month to the mean of all, corresponds very closely to the analogous ratios deduced in a preceding table for the number of disturbances, giving the law in reference to the number and amount of disturbances in a year as the same, or nearly so. The maximum amount of disturbances occurs in October (at Toronto in September), the minimum amount in June (the same at Toronto); the secondary maximum occurs in April (as at Toronto), and the secondary minimum in February; but at Toronto in January, from comparison with the years 1843, 1844, 1845.

The next tables give the aggregate monthly values in the six years, separated into west and east deflections:—

[1] The differences of the disturbed readings from their respective normals during the month of June and part of July, 1840, were first converted from the old scale into equivalent new scale values.

West Deflections.								
Month.	1840.	1841.	1842.	1843.	1844.	1845.	Mean.	Ratio.
	d.	d.	d.	d.	d.	d.	d.	
January . . .	(495.5)	308.4	444.8	(170.4)	23.8	161.6	267.4	1.21
February . . .	(238.0)	147.2	217.1	(82.0)	28.0	69.9	130.4	0.59
March	(288.7)	127.2	168.5	(99.5)	172.8	117.5	162.4	0.73
April	(432.2)	97.9	216.9	98.9	370.1	171.0	229.5	1.04
May	(212.8)	229.5	84.4	109.7	43.5	8.3	114.7	0.52
June	30.9	170.4	194.2	21.7	12.6	65.9	82.6	0.37
July	186.7	51.1	140.5	153.3	28.9	(42.9)	100.6	0.46
August	275.9	228.4	721.3	809.7	304.5	(247.5)	431.2	1.95
September . .	495.3	257.8	116.7	65.2	249.3	(123.5)	217.9	0.99
October . . .	1019.9	422.5	172.5	74.4	340.3	(185.5)	369.2	1.67
November . . .	178.4	586.9	159.6	39.1	267.1	(196.9)	238.0	1.09
December . . .	1210.5	308.2	9.4	17.7	178.8	(98.7)	303.9	1.38
Sum	5064.8	2935.5	2645.9	1741.6	2019.7	1489.2	2647.8	12.00

East Deflections.								
Month.	1840.	1841.	1842.	1843.	1844.	1845.	Mean.	Ratio.
	d.	d.	d.	d.	d.	d.	d.	
January . . .	(27.9)	115.2	141.1	(22.7)	21.5	107.6	72.7	0.33
February . . .	(55.7)	255.1	93.0	(38.5)	71.7	90.2	100.7	0.46
March	(81.8)	200.7	95.9	(53.4)	257.2	49.9	123.2	0.56
April	(116.7)	196.8	264.2	182.8	231.4	118.7	185.1	0.84
May	(66.2)	213.3	100.0	97.1	162.0	102.7	123.6	0.56
June	52.2	185.1	158.9	112.2	37.8	75.3	103.6	0.47
July	482.1	365.7	406.3	118.2	139.4	(177.5)	281.5	1.29
August	342.7	594.7	152.2	144.2	248.1	(194.8)	279.4	1.28
September . .	358.2	984.9	663.2	236.3	199.3	(358.3)	466.7	2.12
October . . .	299.2	953.7	1080.7	120.6	327.8	(453.0)	539.2	2.46
November . . .	136.2	467.3	179.7	48.0	324.0	(187.6)	223.8	1.02
December . . .	71.8	376.4	38.0	16.6	187.4	(116.6)	134.4	0.61
Sum	2090.7	4908.9	3373.2	1190.6	2207.6	2032.2	2633.9	12.00

Maxima in September (mean of August and October) and April; minima in June and January as at Toronto.

The following table gives the aggregate values of the disturbances distributed into the different hours of the day, as deduced from bi-hourly observations made in 1840 to 1845:—

Philadelphia. Hour. (+ 19¼ m.)	Aggregate Values of Western Deflections, Eastern Deflections, and Sum.			Mean Aggregate Values for one year.			Ratios.		
	W.	E.	Sum.	W.	E.	Sum.	W.	E.	Both combined.
	d.	d.	d.	d.	d.	d.			
0h.	897.4	1438.5	2335.9	149.6	239.8	389.4	0.83	1.24	1.04
2	1259.7	1278.2	2537.9	209.9	213.0	422.9	1.16	1.10	1.13
4	1255.5	1075.5	2331.0	209.2	179.3	388.5	1.16	0.92	1.04
6	1581.7	773.6	2355.3	263.6	128.9	392.5	1.46	0.67	1.06
8	1512.4	769.9	2282.3	252.1	128.3	380.4	1.39	0.67	1.02
10	1315.2	901.9	2217.1	219.2	150.3	369.5	1.22	0.77	0.99
Noon	1114.8	733.2	1848.0	185.8	122.2	308.0	1.03	0.63	0.83
14	1056.4	735.0	1791.4	176.1	122.5	298.6	0.98	0.63	0.80
16	1068.1	825.8	1893.9	178.0	137.6	315.6	0.99	0.72	0.85
18	902.1	965.2	1867.3	150.3	160.9	311.2	0.84	0.89	0.84
20	408.9	2175.4	2584.3	68.2	362.6	430.8	0.38	1.88	1.15
22	610.4	2180.3	2790.7	101.7	363.4	465.1	0.56	1.88	1.25
Sum	12982.6	13852.5	26835.1	2163.7	2308.8	4472.5	12.00	12.00	12.00
Mean	...	...	...	180.3	192.4	372.7	...	...	...

If we compare these ratios with the corresponding numbers in the preceding tables, showing the bi-hourly distribution in regard to the number of disturbances, we find, irrespective of the directions of the deflections, the 2 P. M. minimum preserved; the maximum occurs at 10 P. M. At Toronto, from a five years' hourly series, commencing with 1844, these hours are respectively 1 P. M. and 9 P. M. At Philadelphia, as at Toronto, the ratios are nearly invariable from 10 A. M. to 6 P. M., being then below unity; and again from 8 P. M. to 8 A. M., when they are above unity.

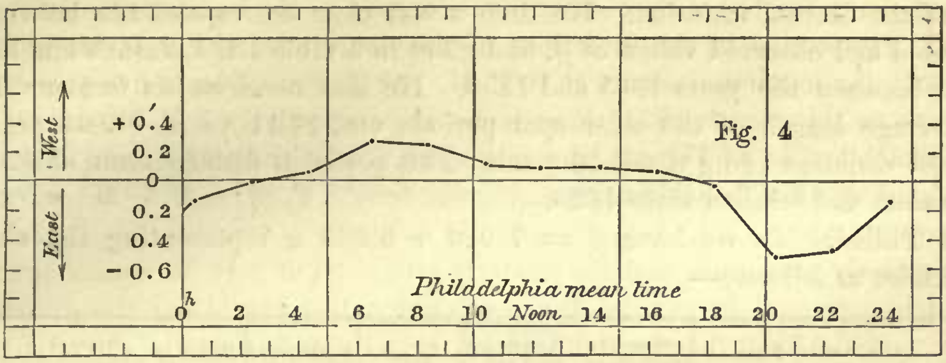
The easterly maximum and the westerly minimum at 8 P. M. appear again as a decided feature, and in general, the respective ratios exhibiting the diurnal distribution of the disturbances, both in an easterly and westerly direction, show almost a perfect correspondence in regard to both number and amount.

The next table exhibits the excess of westerly disturbance over easterly (the sign — indicating a defect, or excess of easterly over westerly) in the aggregate values of the five year series, and in the last column, the mean effect of the same at each even hour, is given as obtained by dividing the aggregate differential value of the preceding column by the actual number of days of observation during the whole period. The last column exhibits, therefore, the mean diurnal disturbance variation. The number of days is very nearly 1500.

Philadelphia mean time.	Excess of westerly over easterly values.	Diurnal Variation caused by the Larger Disturbances.		For comparison: Disturbance—variation at Toronto 1843–'44–'45 (at even hours).	Philadelphia mean time.	Excess of westerly over easterly values.	Diurnal Variation caused by the Larger Disturbances.		For comparison: Disturbance—variation at Toronto 1843–'44–'45 (at even hours).
		In scale divisions.	In minutes of arc.				In scale divisions.	In minutes of arc.	
	d.	d.	′	′		d.	d.	′	′
0h. 19½m.	—541.1	—0.36	—0.16	—0.36	Noon 19½m.	+ 381.6	+0.25	+0.11	+0.09
2 19½	— 18.5	—0.01	—0.01	—0.20	14 19½	+ 321.4	+0.21	+0.10	+0.04
4 19½	+180.0	+0.12	+0.05	—0.03	16 19½	+ 242.3	+0.16	+0.07	+0.03
6 19½	+808.1	+0.54	+0.24	+0.02	18 19½	— 63.1	—0.04	—0.02	—0.16
8 19½	+742.5	+0.50	+0.22	+0.10	20 19½	—1766.5	—1.18	—0.53	—0.56
10 19½	+413.3	+0.28	+0.13	+0.06	22 19½	—1569.9	—1.05	—0.47	—0.75

The law governing the disturbances during a solar day is clearly shown, and systematic in character. If we plot the disturbance curve on the same scale, or actually superpose it on the curves of the regular diurnal variation, the difference would hardly show to the eye. The diagram, showing the disturbance variation, has, therefore, been plotted on a larger scale. (See Fig. 4.)

DIURNAL DISTURBANCE VARIATION OF THE DECLINATION.



The curve has but one maximum and one minimum; its most prominent feature is the easterly deflection at 8 o'clock (+19½^{m}) P. M. (at Toronto it is at 9 P. M.). At that hour the maximum deflection amounts to 32″ of arc, and to 45″ at Toronto. The greatest westerly deflection occurs at 6^{h} (+19½^{m}) A. M., and amounts to but 14″; the Toronto hour is 8 A. M. with 6″, and from a five years' series of observation, with 31″ of deflection. The range of the disturbance variation equals 46″.[1] The disturbance amplitude, as well as the regular variation amplitude, is greater at Toronto than at Philadelphia, the occurrence of the maximum and minimum disturbance deflection seeming to be about one hour earlier at the latter station. From three in the morning till five in the afternoon the mean effect of the disturbances is to deflect the north end of the magnet to the west, and during the remaining hours (principally at night) to the east. The westerly and easterly disturbance deflections during a day balance within 0′.02.

The annual inequality in the amplitude of the diurnal disturbance variation might be satisfactorily shown by the proper combination of the results for consecutive years, comparing each two-year series successively; but owing to the small amount of the amplitude itself, and the incomplete or partly interrupted series of observations in the years 1840, 1843, and 1845, it was thought best to restrict the present discussion to the mean disturbance variation.

It is my intention to continue the discussion of the observations made at the Girard College Observatory.

After the above was written,[2] No. 1185 of the *Astronomische Nachrichten* came to hand, containing Prof. R. Wolf's interesting results on the close connection of the variation in frequency of the solar spots, and the corresponding inequality in the amplitude of the diurnal variation of the declination. He deduces for Munich the formula $\beta = 6'.273 + 0'.051\ a$ in which a is a relative number expressive of

[1] At Toronto 51″, and from a five years' series 83″.

[2] For former communications by Prof. R. Wolf, see Nos. 839, 1043, 1091, 1132, 1160, and 1181, *ibid.*

the frequency of the solar spots directly derived from observation and β the amplitude of the diurnal variation. He finds a very close correspondence between the computed and observed values of β, and gives in a table Dr. Lamont's and his own results between the years 1835 and 1850. He also reaffirms his former value for the average length of the solar spot period., viz., 11.11 years $\pm$ 0.04 years, the limits of variation being 8 and 16 years. This period is deduced from observations of maxima and minima since 1626.

For Philadelphia we have $\beta = 7'.080 + 0'.039\ \alpha$ representing the observed amplitudes as follows:—

Year.	α (from solar spot) observations.	β derived from α.	Observed amplitude, or β.	Difference obs'd and comp'd β.	Year.	α (from solar spot) observations.	β derived from α.	Observed amplitude, or β.	Difference obs'd and comp'd β.
1840	51.8	9'.10	9'.08	—0'.02	1843	8.4	7.'41	7'.46	+0'.05
1841	29.5	8.23	8.06	—0.17	1844	12.2	7.55	7.51	—0.04
1842	19.2	7.83	7.83	0.00	1845	32.4	8.34	8.53	+0.19

The correspondence between the observed diurnal amplitude and the same derived from observations of the solar spots is further exhibited by Fig. 5, the heavy line representing the magnetic, the other the solar amplitude curve. The dotted curve is from the Toronto magnetic observations, merely multiplied by $\frac{8}{9}$ to reduce (approximately) to the Philadelphia scale. The next maximum amplitude, according to the solar spot observations, would be in 1848, amounting to 11'.00; and the whole range of the inequality in the amplitude of the diurnal motion would, therefore, be 11'.00 — 7'.46 = 3'.54. The last quantity, it must be observed, is slightly variable with each period; thus, according to the solar spot observations, the year 1837 was a maximum, amplitude 11'.41; and the year 1856 a minimum, amplitude 7'.24, the difference being 4'.17.

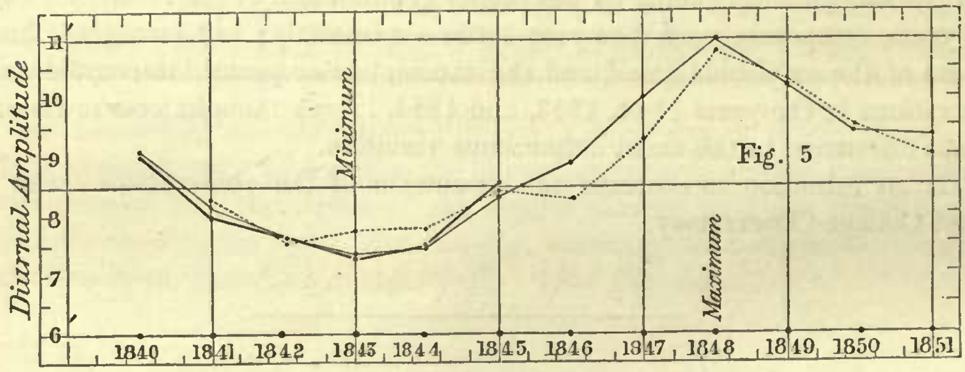


Fig. 5

It is much to be desired that this interesting branch of physical inquiry should be further studied, as it forms one of the links connecting terrestrial with cosmical phenomena.